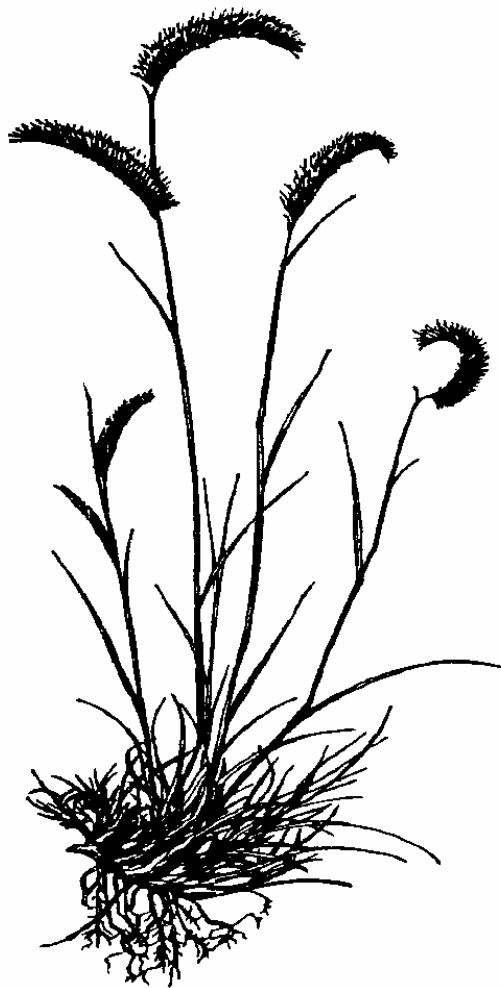




Baseline Plant Community Monitoring Report, Tallgrass Prairie National Preserve

Natural Resource Technical Report NPS/MWR/HTLN/NRTR—2006/001



ON THE COVER

Boutaloua gracilis (Willd. ex Kunth) Lag. ex Griffiths
Line drawing from Hitchcock (1950).

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Introduction

The tallgrass prairie ecosystem once spread across more than 60 million hectares and extended from southern Texas to southern Manitoba (Collins and Glenn 1998). Now, however, it is estimated that as little as 1-4% (0.6-2.4 million ha) of the original tallgrass prairie remains (Weaver 1954). In addition to being highly fragmented and disparate, tallgrass prairie remnants tend to occur on sites of marginal agricultural use, usually steep slopes with rocky soils.

Historically, native tallgrass prairie was characterized by heterogeneity, with vegetation communities occurring in a patchwork of various conditions. The interaction of fire, grazing and climate formed a landscape in which few patches were burned or grazed at the same time or intensity every year (Hiebert 1998). It is estimated, using time until tree invasion under fire suppression, that historic grassland fire return intervals ranged from 3 to 5 years (Collins and Glenn 1995). In general, fires were relatively small in size (NPS 2000) and occurred in all seasons (Bragg 1995). Variability in fire frequency and size led to spatially variable grazing as native ungulates preferentially grazed newly burned patches. Non-grazing behaviors, such as wallowing, also increased landscape heterogeneity (Plumb and Dodd 1993).

The interaction of fire, grazing and climate affect ground flora composition and abundance in any given year (Albertson et al. 1957, Hartnett et al. 1996), often-making tallgrass prairies difficult communities to manage. However, the complexity of these ecosystems creates the potential for high biodiversity.

Tallgrass Prairie National Preserve (TAPR) is the first National Park Service area established specifically for the preservation, protection and interpretation of the tallgrass prairie ecosystem (Hiebert 1998). Formerly known as the Spring Hill Ranch area and continuously grazed for cattle production for over 120 years, TAPR consists of more than 9,000 acres of unplowed tallgrass prairie in the Flint Hills physiognomic province of Kansas. Land management of TAPR, under the current grazing lease, calls for early intensive stocking (EIS) of cattle and annual spring burning. This management does not fully simulate the temporal or spatial variability characteristic of a native tallgrass ecosystem, particularly the seasonality and behavior of fire. The approved TAPR General Management Plan (GMP) calls for a shift to a spatially and temporally variable fire and grazing regime. Starting in 2001, initial changes were made to decrease fire frequency and implement EIS with lighter stocking rates in the two southern pastures (Redhouse and Crusher, Table 1). However, Redhouse did receive higher than prescribed stocking in 2002, while Gashouse received less than prescribed stocking (although still more than Redhouse and Crusher) for 2001, 2002 and 2003.

Table 1. Years of prescribed burning in four pastures at TAPR.

Pasture	1997	1998	1999	2000	2001	2002	2003
Windmill	X	X	X	X	X	X	X
Gashouse	X	X	X	X	X	X	X
Redhouse	X	X	X			X	
Crusher	X	X	X	X	X		X

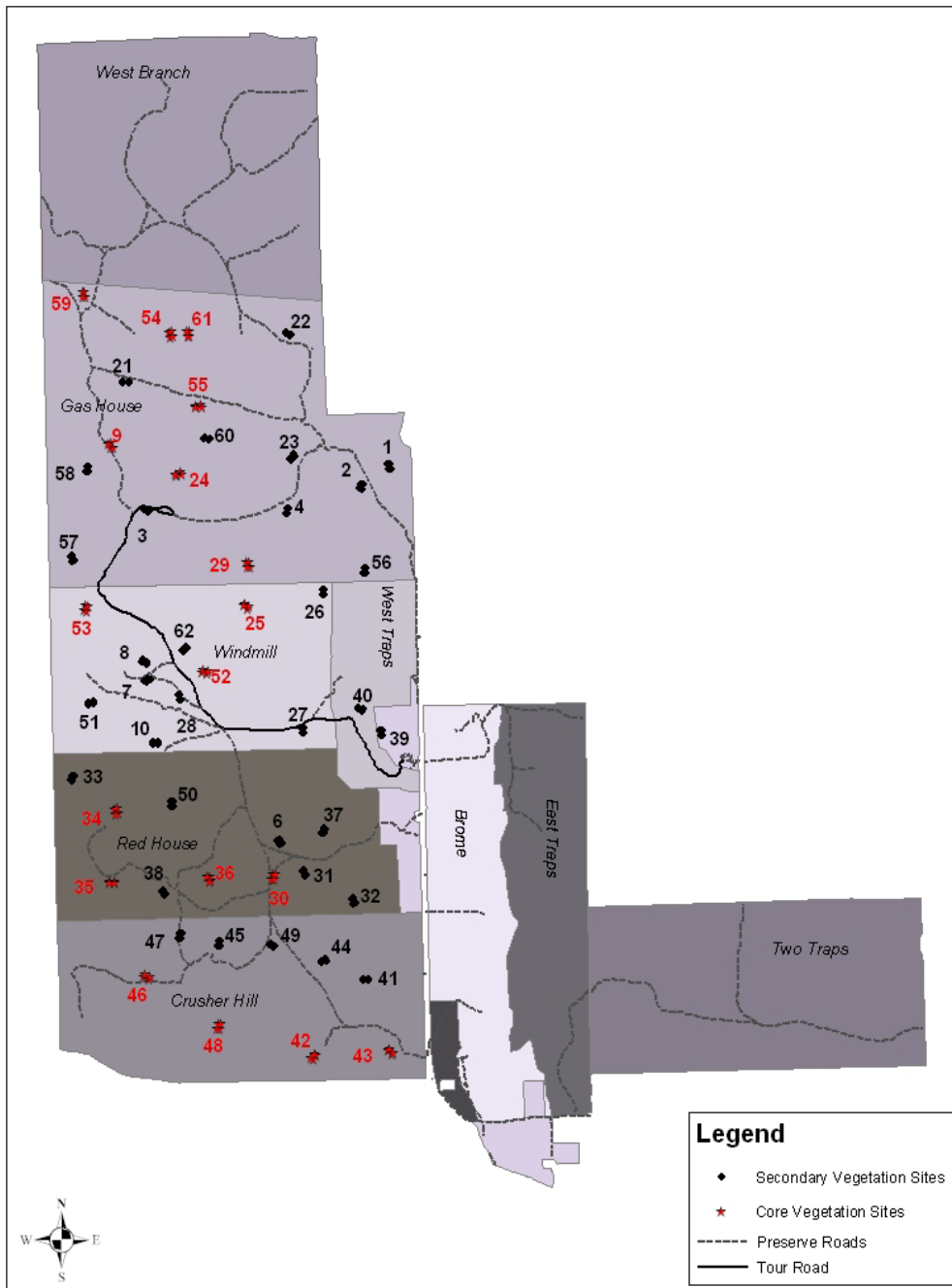


Figure 1. Map of TAPR showing pastures and HTLN core and secondary sites.

Methods

Field Methods

The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) implemented monitoring at TAPR in 2000 to provide analysis of baseline conditions and to assess future change in floral communities (see Willson et al. 2002 for detailed information on monitoring protocol). Forty-nine sample sites were established during the 2000-2001 period throughout four pastures at TAPR (Fig. 1). Current analysis focuses on 18 core plots that have been monitored for the last two years (2002-2003), encompassing the major soils and corresponding plant communities on TAPR. The years of 2000-2001 primarily focused on establishing permanent sample sites and the small amount of data from these years was not a focus for analysis. Secondary plots were also established to encompass the range of soils present at TAPR, but are sampled less frequently. A smaller set of data is available ranging back to 1997 for the northern two pastures (Gashouse and Windmill; Eddy 1999), which is useful for comparison of long-term trends in species groups. Data are collected each year in two sampling trips, one in late spring and one in early fall. In this way, accurate cover estimates and identification of warm season grasses and summer/fall flowering forbs can occur.

The HTLN sampling design, based on the design of the Konza Prairie Long-Term Ecological Research Program, consists of randomly located, permanent, paired transects 50 m long and 20 m apart with five circular 10 m² plots systematically spaced along each transect (Fig. 2). Each 10 m² plot also includes nested subplots of 1 m², 0.1 m² and 0.01 m² for frequency estimates at multiple scales. Working systematically from the smallest subplot (0.01 m²) to the largest (10 m²), all species are identified and foliar cover is estimated.

Analytical Methods

Given the complexity of ecological drivers in the prairie ecosystem, community composition at TAPR is assessed with several metrics. Measuring foliar cover of species, calculating species frequency, richness, diversity and the exotic/native ratio are among the means used to assess community composition.

As well as analysis of individual species, plants guilds are also assessed at TAPR. Often the use of plant guilds can be a helpful analytical tool for understanding ecological patterns and processes. Generally, plant guilds are classified by shared features, such as structural morphology, photosynthetic processes, drought tolerance, and the presence of woody tissue. These features generally reflect differences in the way resources such as light, water and nutrients are obtained. Guilds simplify the array of species into groups making ecosystem processes and functions more easily understood (Kindscher 1994). The use of plant guilds can also compensate for errors related to field sampling identification.

Additionally, a species classification using response to management can be useful for analysis. John Weaver (1954) observed that prairie species respond differently to grazing and created the use of the terms “increasers and decreaseers” based on the observation. Decreasers are those species that are more palatable to cattle and/or are affected by the physical presence of large ungulates and decline in abundance and size under grazing pressure. Conversely, increasers are non-palatable prairie species that increase in abundance and size under intense grazing pressure

due to such factors as decreased competition or change in physical environment. An abundance of increaser species could indicate possible overgrazing in the tallgrass prairie. Conversely, an abundance of decreasers could indicate overall “good” health of a prairie. This classification allows for a quick qualitative analysis of the condition of the prairie (Fraser and Kindscher 1997). Frequency and cover of 14 increaser species and 13 decreaser species was analyzed over the baseline period of 2002-2003 at TAPR.

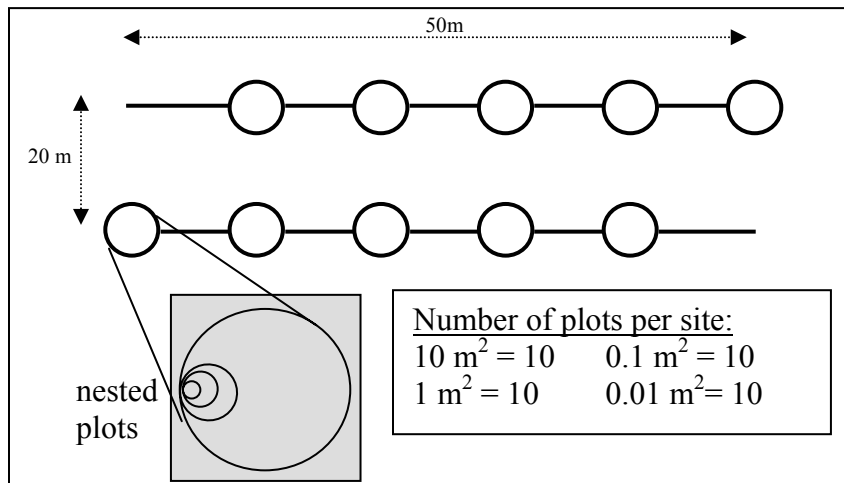


Figure 2. Vegetation community sampling design used by the Heartland network showing transects and plots including nested plots.

Analyzing patterns in species richness at both the sample site and the preserve-wide level allows three kinds of diversity to be calculated for TAPR (Whittaker 1972). Alpha diversity, local level diversity, is calculated as the average species richness per sample site, while gamma diversity, landscape level diversity, is estimated as the total number of species across all sample sites (McCune and Mefford 1997). Beta diversity, as a measure of the heterogeneity in the data, is calculated as (Whittaker 1972):

$$\beta_w = (S_c / S) - 1$$

where:

β_w = beta diversity,

S_c = the number of species in the composite sample,

S = the average species richness in the sample units.

As a rule of thumb, values of $\beta_w < 1$ are rather low and $\beta_w > 5$ are considered high beta diversity (McCune and Grace 2002). If $\beta_w = 0$, then all sample units have all of the species. The one is subtracted to make zero beta diversity correspond to zero variation in species presence. While this measure does not have any formal units, the result can be thought of in approximate units as the “number of distinct communities” (McCune and Grace 2002).

Results

Baseline Conditions

During the 2002-2003 sampling period, 158 unique species were found on HTLN sample sites at TAPR including 40 families. Annual richness (gamma diversity) ranged from 130 to 147 species with few exotics (Tables 2 and 3). On average, 57 species were found per sample unit (alpha diversity) resulting in an average, preserve-wide measure of beta diversity of 1.43 (Table 4). Warm season grasses such as indiagrass (*Sorghastrum nutans* (L.) Nash) and big bluestem

Table 2. Plant community composition: species richness and shannon diversity.

Measure	2002	2003	2-Year Avg. (SD)
All Species			
Richness	130	147	138.5 (12.02)
Total Diversity	2.71	3.27	2.99 (0.40)
Mean Diversity (SD)	2.39 (0.35)	2.88 (0.25)	2.64 (0.35)
Total Evenness	0.56	0.66	0.61 (0.07)
Mean Evenness (SD)	0.61 (0.08)	0.70 (0.05)	0.66 (0.06)
Native Species Only			
Richness	124	135	129.5 (7.78)
Total Diversity	2.70	3.23	2.97 (0.37)
Mean Diversity (SD)	2.38	2.86	2.62 (0.34)
Total Evenness	0.56	0.66	0.61 (0.07)
Mean Evenness (SD)	2.38	2.86	2.62 (0.34)

Table 3. Plant community composition: relative frequency and cover of exotic species.

Measure	2002	2003	2-Year Avg. (SD)
Exotic Species	5	10	7.5 (3.54)
Native Species	124	135	129.5 (7.78)
Ratio E/(E+N)	0.039	0.069	0.054 (0.02)
Exotic Species			
Relative Frequency	0.79%	2.10%	1.45% (0.93)
Relative Cover	0.21%	0.88%	0.55% (0.47)
Native Species			
Relative Frequency	99.21%	97.90%	98.55% (0.93)
Relative Cover	99.79%	99.12%	99.45% (0.47)

Table 4. Three levels of diversity for entire TAPR preserve, as well as four pastures for baseline years of 2002 and 2003.

Pasture	N	alpha		beta		gamma	
		2002	2003	2002	2003	2002	2003
Gashouse	7	49.6	61.9	0.75	0.97	87	122
Windmill	3	60.0	62.3	1.53	1.43	92	89
Redhouse	4	53.2	63.2	1.71	1.61	91	102
Crusher	4	48.5	61.5	1.79	1.77	87	109
Entire Preserve	18	51.9	62.2	1.50	1.36	130	147

(*Andropogon gerardii* Vitman) are the major components of the flora, ranging from 53 to 75% of the floral coverage within a sample site depending on the year (Tables 5 and 6). Less significant but still prominent components of the flora at TAPR include cool-season grasses such as Junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes) and buffalo grass (*Buchloe dactyloides*

Table 5. Plant community composition: relative cover of native plant guilds.

Plant Guild	2002	2003	2-Year Avg. (SD)
Annuals/Biennials	0.87%	11.21%	6.04% (7.31)
Cool Season Grasses	5.15%	8.30%	6.73% (2.23)
Ephemeral Spring Forbs	1.48%	1.69%	1.59% (0.15)
Grass-like	1.37%	1.97%	1.67% (0.42)
Legumes	1.42%	2.99%	2.21% (1.11)
Spring Forbs	2.59%	3.35%	2.97% (0.54)
Succulents	0.05%	0.09%	0.07% (0.03)
Summer/Fall Forbs	5.89%	12.57%	9.23% (4.72)
Warm Season Grasses	75.27%	52.50%	63.89% (16.1)
Woody Shrubs and Vines	5.77%	5.06%	5.42% (0.50)

Table 6. Plant community composition: relative frequency of native plant guilds.

Plant Guild	2002	2003	2-Year Avg. (SD)
Annuals/Biennials	3.30%	14.28%	8.79% (7.76)
Cool Season Grasses	10.45%	8.79%	9.62% (1.17)
Ephemeral Spring Forbs	6.94%	6.16%	6.55% (0.55)
Grass-like	4.85%	3.63%	4.24% (0.86)
Legumes	6.47%	7.06%	6.77% (0.42)
Spring Forbs	9.85%	9.42%	9.64% (0.30)
Succulents	0.26%	0.19%	0.23% (0.05)
Summer/Fall Forbs	21.51%	20.41%	20.96% (0.78)
Warm Season Grasses	31.73%	26.11%	28.92% (3.97)
Woody Shrubs and Vines	4.05%	3.40%	3.73 (0.46)

(Nutt.) Englem.), grass-like species of sedges and rushes, woody species including dwarf prairie rose (*Rosa arkansana* Porter) and smooth sumac (*Rhus glabra* L.), showy spring forbs such as butterfly milkweed (*Asclepias tuberosa* L.), 26 species of summer and fall flowering forbs, 15 species of legumes and two cacti.

Most species guilds showed little inter-annual variation between 2002 and 2003 (Tables 5 and 6). However, two species guilds did show significant differences between 2002 and 2003. The annuals and biennials showed significantly higher frequency and cover in 2003 than 2002, while warm season grasses had lower cover in 2003 than 2002.

Exotics, most notably Kentucky bluegrass (*Poa pratensis* L.) and redseed plantain (*Plantago rhodosperma* Dcne.), comprise only a small component of the vegetation at TAPR (Table 7). Dominant species (i.e. those with high importance values) include native species such as big bluestem, little bluestem (*Schizachyrium scoparium* (Michx.) Nash), side-oats grass-grass (*Bouteloua curtipendula* (Michx.) Torr.) and lead plant (*Amorpha canescens* Pursh) (Table 8) (see Appendix for full species list). As expected, grass and grass-like species dominated the community structure with a mean cover of 46%, with very little shrub cover (4%) (Table 9). Unvegetated ground was predominantly bare soil (59%) with some grass litter (32%) (Table 10).

Table 7. Plant community composition: exotic species.

Species	Common Name	Frequency	Mean Cover	Importance Value (SD)
<i>Plantago rhodosperma</i>	Plantain	22.50%	0.52%	0.00425 (0.00272)
<i>Poa pratensis</i>	Kentucky	14.17%	1.34%	0.00385 (0.00039)
<i>Digitaria ischaemum</i>	Smooth crabgrass	1.95%	0.43%	0.00055 (0.00039)
<i>Veronica arvensis</i>	Corn speedwell	1.95%	0.25%	0.00035 (0.00025)
<i>Stellaria media</i>	Common	1.67%	0.46%	0.00035 (0.00025)
<i>Lactuca serriola</i>	Prickly lettuce	1.11%	0.25%	0.0002 (0.00014)
<i>Lepidium campestre</i>	Field-cress	0.56%	0.25%	0.0001 (0.00007)
<i>Thlaspi arvense</i>	Field penny-cress	0.56%	0.25%	0.0001 (0.00007)
<i>Capsella bursa-pastoris</i>	Shepherd's purse	0.56%	0.50%	0.0001 (0.00)
<i>Setaria viridis</i>	Green foxtail-	0.28%	0.25%	0.00005 (0.00004)
<i>Rumex crispus</i>	Curly dock	0.28%	0.25%	0.00005 (0.00004)
<i>Arenaria serpyllifolia</i>	Thyme leaf	0.28%	0.25%	0.00005 (.000004)

Table 8. Plant community composition: herbaceous and shrub species with an importance value greater than 0.02 (all species listed in Appendix).

Species	Common Name	Frequency	Mean Cover	Importance Value (SD)
<i>Andropogon gerardii</i>	Big bluestem	99.44%	15.25%	0.1336(0.0371)
<i>Schizachyrium scoparium</i>	Little bluestem	99.72%	7.34%	0.07535(0.0303)
<i>Boufeloua curtipendula</i>	Side-oats grama-grass	98.06%	7.37%	0.07535(0.0139)
<i>Amorpha canescens</i>	Lead-plant	98.06%	3.51%	0.0445(0.0051)
<i>Buchloe dactyloides</i>	Buffalograss	67.50%	4.51%	0.0362(0.0116)
<i>Panicum virgatum</i>	Switchgrass	89.45%	2.62%	0.03435(0.01)
<i>Bouteloua hirsuta</i>	Hairy grama-grass	58.61%	4.23%	0.0302(0.0106)
<i>Sorghastrum nutans</i>	Indian grass	93.06%	1.78%	0.02985(0.011)
<i>Sporobolus asper</i>	Tall dropseed	93.61%	1.83%	0.0298(0.0016)
<i>Amphiachyris dracunculoides</i>	Broomweed	43.34%	3.30%	0.0265 (0.0368)
<i>Symphyotrichum ericoides</i>	Squarrose white wild aster	84.72%	1.52%	0.0256 (0.0078)
<i>Carex</i> spp.	Sedges	97.22%	0.10%	0.0251 (0.00)
<i>Ambrosia psilostachya</i>	Western ragweed	90.28%	1.08%	0.02375(0.005)
<i>Eragrostis spectabilis</i>	Purple lovegrass	93.61%	0.83%	0.0231 (0.0023)
<i>Vernonia baldwinii</i>	Western ironweed	76.95%	1.37%	0.0225 (0.0035)
<i>Bouteloua gracilis</i>	Blue grama	36.39%	5.69%	0.02125(0.0043)
<i>Dichanthelium</i> spp.	Panic grasses	92.22%	0.59%	0.02115(0.0036)

Table 9. Plant community structure: mean percent cover for the shrub and herbaceous layers.

Plant Type	2002	2003	2-Year Avg. (SD)
Grasses/Grass-like	52.85	40.09	46.47 (9.02)
Herbs	7.47	20.05	13.76 (8.90)
Shrubs	4.10	3.49	3.80 (0.43)

Table 10. Plant community structure: mean percent cover for the ground layer.

Structural Component	2002	2003	2-Year Avg. (SD)
Bare Soil	59.11	58.10	58.61 (0.71)
Bare Rock	9.24	11.61	10.43 (1.68)
Grass Litter	37.72	26.94	32.33 (7.62)
Woody Debris	0.04	0.07	0.06 (0.02)
Leaf Litter	0.04	0.07	0.06 (0.02)
Unvegetated Surface	86.81	86.04	86.43 (0.54)

As a qualitative measure of prairie health, the frequency and abundance of increaser and decreaser species, as defined by Fraser and Kindscher (1997) was inconclusive. Certain forb species commonly associated with heavy grazing (i.e. western ironweed, *Vernonia baldwinii* Torr. and white heath aster, *Symphyotrichum ericoides* (L.) Nesom) occur at conspicuously high frequencies in the prairie. On the other hand, other species classified as increasers such as clammy ground cherry (*Physalis heterophylla* Nees) and hoary verbena (*Verbena stricta* Vent.) are present only negligibly (Table 11).

Table 11. Average frequency and cover of plant species classified by Fraser and Kindscher (1997) as increasing or decreasing with intensive grazing pressure.

Scientific Name	Common Name	Grazing	Average Frequency (%)		Average Cover (%)	
			2002	2003	2002	2003
<i>Amorpha canescens</i>	leadplant	decreaser	97.78	98.33	3.85	3.16
<i>Andropogon gerardii</i>	big bluestem	decreaser	99.44	99.44	18.81	11.67
<i>Aster sericeus</i>	western silvery wild	decreaser	7.22	8.33	0.11	0.15
<i>Astragalus</i>	ground plum, prairie	decreaser	5.00	10.56	0.14	0.28
<i>Comandra umbellata</i>	bastard toad-flax	decreaser	0.56	0.56	0.03	0.03
<i>Dalea candida</i>	white prairie clover	decreaser	1.67	3.33	0.08	0.11
<i>Dalea purpurea</i>	purple prairie clover	decreaser	46.11	47.22	0.42	0.36
<i>Elymus canadensis</i>	Canada wild rye	decreaser	3.33	5.00	0.11	0.11
<i>Panicum virgatum</i>	switchgrass	decreaser	83.33	95.56	1.58	3.33
<i>Psoralea esculenta</i>	bread root scurf-pea	decreaser	7.78	18.33	0.19	0.33
<i>Rosa arkansana</i>	dwarf prairie rose	decreaser	1.67	1.67	0.06	0.06
<i>Sisyrinchium</i>	blue-eyed grass	decreaser	25.56	32.78	0.39	0.47
<i>Viola pedatifida</i>	prairie violet	decreaser	22.78	21.67	0.28	0.28
<i>Achillea millefolium</i>	common yarrow	increaser	28.33	28.89	0.47	0.42
<i>Antennaria neglecta</i>	field pussytoes	increaser	22.22	26.67	0.50	0.65
<i>Artemisia ludoviciana</i>	white sage	increaser	37.78	33.89	0.75	0.71
<i>Asclepias verticillata</i>	whorled milkweed	increaser	13.89	16.11	0.31	0.31
<i>Symphyotrichum</i>	white heath aster	increaser	82.22	87.22	0.57	2.30
<i>Baptisia bracteata</i> v. <i>leucophaea</i>	plains wild indigo	increaser	6.67	13.89	0.24	0.97
<i>Buchloe dactyloides</i>	buffalograss	increaser	61.11	73.89	2.66	4.90
<i>Eragrostis spectabilis</i>	purple lovegrass	increaser	92.78	94.44	0.83	0.81
<i>Erigeron strigosus</i>	rough fleabane	increaser	7.22	1.67	0.08	0.08
<i>Physalis heterophylla</i>	clammy ground cherry	increaser	0.00	1.11	0.00	0.06
<i>Poa pratensis</i>	Kentucky bluegrass	increaser	12.78	15.56	0.21	0.45
<i>Solidago missouriensis</i>	Missouri goldenrod	increaser	9.44	45.00	0.31	0.52
<i>Verbena stricta</i>	hoary verbena	increaser	7.78	9.44	0.17	0.22
<i>Vermonia baldwinii</i>	western ironweed	increaser	75.56	78.33	0.79	1.75

Preliminary Trend Detection

Given differences in sample effort since 1997 and the evolution of taxonomic knowledge, it is not yet possible to comment on trends in the effect of management activity at TAPR since 1997 on individual species. However, it is possible to examine general trends in the abundance of groups of species, since they are less affected by sampling error. Since 1997, cover of warm season grasses has varied significantly year to year, perhaps due to weather (Fig. 3). Meanwhile, cool-season grasses have shown a steady increase (Fig. 3), while annuals/biennials had high abundance in 2001 and 2003. The annual species broomweed (*Amphichyris dracunculoides* (DC.) Nutt.) was seen in vast abundance in both 2001 and 2003 (Fig. 4).

Preliminary Comparison of Management Regimes

Preliminary changes to fire return intervals and stocking rates have not resulted in significant differences between pastures for the metrics measured. Preliminary results indicate that Redhouse, with reduced fire and stocking, had a slightly greater increase in annuals and biennials

in 2003 than Windmill, but less of an increase in summer forbs than Windmill and Crusher (Fig. 5). Research at Konza Prairie LTER Program also found increased forb cover with increased fire frequency in grazed prairie (Knapp et al. 1998). It may be too early to see significant changes in plant guilds caused by initial changes in fire frequency in Crusher and Redhouse pastures. The pastures with reduced fire and stocking showed decreases in beta diversity from 2002 to 2003, as did Windmill pasture (Table 3). Gashouse was the only pasture to show increased beta diversity.

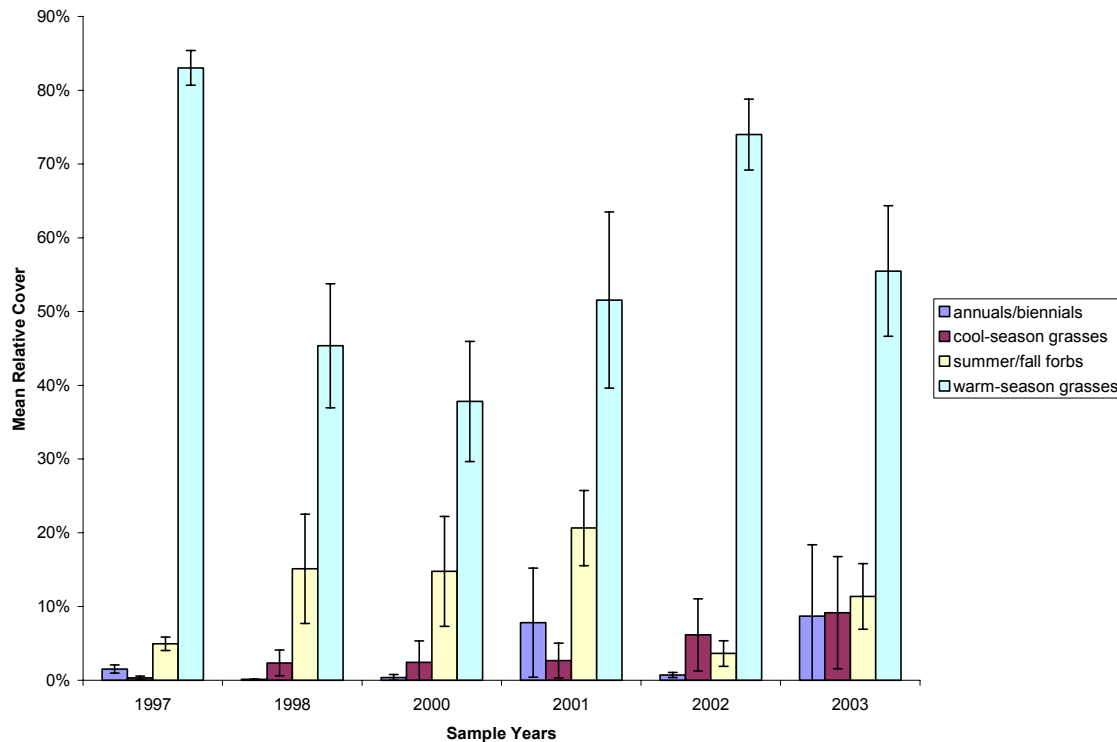


Figure 3. Average guild abundance over entire sampling period at TAPR for northern two pastures (Windmill and Gashouse).



Figure 4. October 2003 landscape at TAPR showing yellow patches of broomweed, *Amphiachyris dracunculoides* (DC.) Nutt.

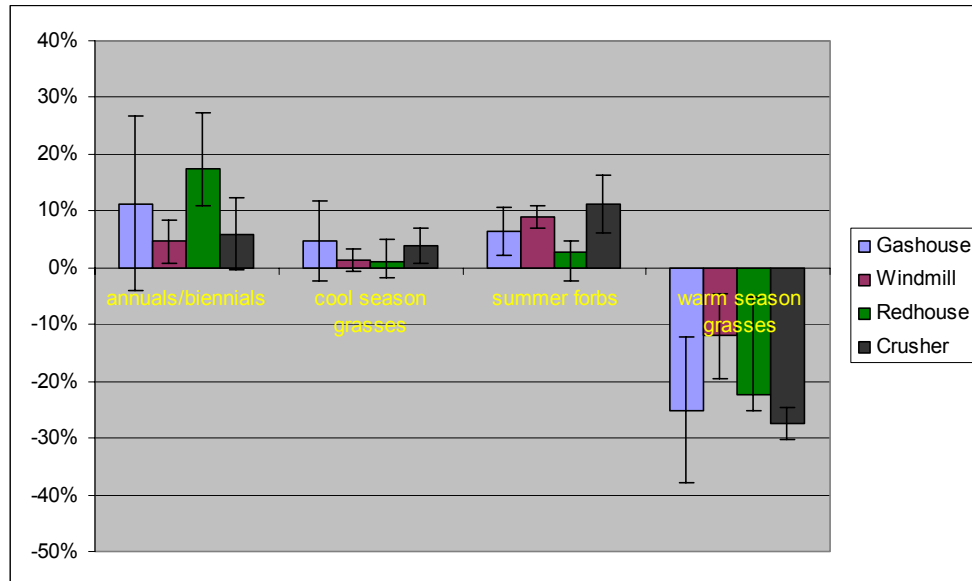


Figure 5. Percent change in abundance of plant guilds for each pasture 2002 to 2003.

Discussion

Early intensive grazing and annual spring burning, implemented in the last 20+ years, has had an overall homogenizing effect on the landscape. This is reflected by the low beta diversity seen preserve-wide. Alternate management, such as reduced stocking and a variable fire regime, may increase beta diversity. So far, the minor modifications to the stocking rate (except Windmill pasture) and the fire frequency (Redhouse and Crusher pastures only) have not improved heterogeneity across the preserve.

While possibly increasing landscape heterogeneity, longer fire return intervals can also allow more annuals/biennials to become established and potentially increase invasive and exotic species previously controlled by frequent fire. While annuals and biennials have increased at TAPR, especially in Redhouse, exotics are still relatively absent. As heterogeneity of fire and grazing increases at TAPR, existing exotics could increase in frequency or abundance. Additionally, while the use of grazing indicator species (Fraser and Kindscher 1997) was inconclusive as a means of quickly assessing the health of the prairie, increasers and decreasers will continue to be monitored in the future as management changes.

In addition to grazing and fire, climatic variability is an important factor driving plant community dynamics at TAPR, with species responding to variability in annual precipitation. Precipitation in 2003 is the first since 1999 to be above the 30-year average (Fig. 6). Increases in annuals/biennials occurred in 2001 and 2003, most notably broomweed. Towne and Owensby (1983) found that increased bare ground resulting from a combination of drought, grazing, mowing and/or fire significantly increased the amount of broomweed in the Kansas Flint Hills. At TAPR, significant increases in broomweed occurred preserve-wide without regard to management regimes. Photopoint interpretation has also captured a negative effect of low precipitation levels on perennial forbs at TAPR (Barnard 2003).

It is still too early to determine the effects of changes in cattle stocking and fire frequencies on the warm season grass component of TAPR. Year-to-year and within-year changes in abundance make short-term detection of management effects on warm season grasses difficult. Future work, including better estimates of frequency for warm season grasses through ancillary sampling, will likely increase knowledge of changes in abundance of plant guilds and the effects of change in management regimes. Future monitoring results when compared to the baseline period should provide a good measure of future management.

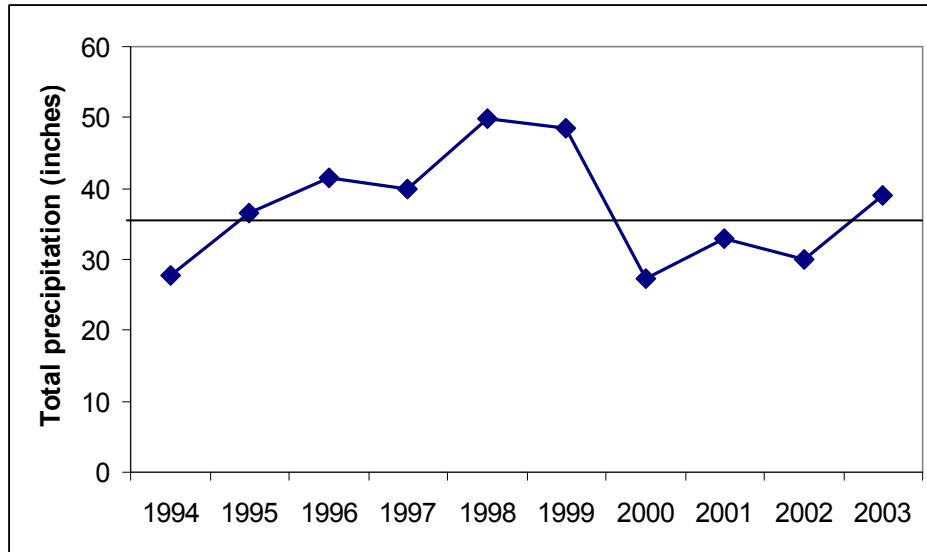


Figure 6. Thirty year averages for precipitation at TAPR 1994 to 2003. (Weather data acquired from Missouri State Climatologist for weather station ID 148061 located at TAPR.)

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Appendix. Species list for Tallgrass Prairie National Preserve including years 1997 to 2003.

Guilds: annual-biennial = opportunistic herbaceous species that complete life cycle in one or two years; coolgrass = cool season grass, members of Poaceae, initiate flowering prior to July; ephemeral = herbaceous spring forbs characterized by short flowering period in spring (typically in late March or April), foliage dries up by early summer; grass-like = species which resemble grasses in their growth form and morphology, terrestrial members of Juncaceae and Cyperaceae; legume = members of Fabaceae, capable of fixing nitrogen through root nodules; spring forb = herbaceous species that initiate flowering prior to June, but persist through summer months; summer/fall forb = herbaceous, initiate flowering in or after July; warmgrass = warm season grass, members of Poaceae, flowering in or after July; woody = perennial species with over wintering aboveground structures, includes trees, shrubs and woody vines; succulents = perennial succulent herbs, shrubs and small trees.

Scientific name	Common Name	Family	Guild
<i>Acalypha ostryifolia</i>	Pineland threeseed mecury	Euphorbiaceae	annual-biennial
<i>Acalypha virginica</i>	Virginia threeseed mecury	Euphorbiaceae	annual-biennial
<i>Achillea millefolium</i>	Common yarrow	Asteraceae	ephemeral
<i>Agalinis aspera</i>	Tall false foxglove	Scrophulariaceae	annual-biennial
<i>Agalinis tenuifolia</i>	Slenderleaf false foxglove	Scrophulariaceae	annual-biennial
<i>Ageratina altissima</i>	White snakeroot	Asteraceae	summer/fall forb
<i>Agrostis hyemalis</i>	Winter bentgrass	Poaceae	coolgrass
<i>Alliaria petiolata</i>	Garlic-mustard	Brassicaceae	annual-biennial
<i>Allium canadense</i>	Meadow garlic	Liliaceae	spring forb
<i>Alopecurus carolinianus</i>	Carolina foxtail	Poaceae	coolgrass
<i>Ambrosia psilostachya</i>	Cuman ragweed	Asteraceae	summer/fall forb
<i>Ambrosia trifida</i>	Great ragweed	Asteraceae	annual-biennial
<i>Amorpha canescens</i>	Lead-plant	Fabaceae	woody
<i>Amphiachyris dracunculoides</i>	Prairie broomweed	Asteraceae	annual-biennial
<i>Andropogon gerardii</i>	Big bluestem	Poaceae	warmgrass
<i>Androsace occidentalis</i>	Western rockjasmine	Primulaceae	annual-biennial
<i>Antennaria neglecta</i>	Field pussytoes	Asteraceae	spring forb
<i>Apocynum cannabinum</i>	Indianhemp	Apocynaceae	spring forb

Scientific name	Common Name	Family	Guild
<i>Arctium minus</i>	Lesser burdock	Asteraceae	annual-biennial
<i>Arenaria serpyllifolia</i>	Thyme leaf sandwort	Caryophyllaceae	annual-biennial
<i>Aristida oligantha</i>	Prairie three-awn	Poaceae	warmgrass
<i>Artemisia ludoviciana</i>	White sagebrush	Asteraceae	summer/fall forb
<i>Asclepias stenophylla</i>	Slimleaf milkweed	Asclepiadaceae	summer/fall forb
<i>Asclepias syriaca</i>	Common milkweed	Asclepiadaceae	spring forb
<i>Asclepias tuberosa</i>	Butterfly-milkweed	Asclepiadaceae	spring forb
<i>Asclepias verticillata</i>	Whorled milkweed	Asclepiadaceae	spring forb
<i>Asclepias viridiflora</i>	Greencomet milkweed	Asclepiadaceae	summer/fall forb
<i>Asclepias viridis</i>	Green antelopehorn	Asclepiadaceae	spring forb
<i>Aster drummondii</i>	Drummond's aster	Asteraceae	summer/fall forb
<i>Aster ericoides</i>	White heath aster	Asteraceae	summer/fall forb
<i>Aster laevis</i>	Smooth blue aster	Asteraceae	summer/fall forb
<i>Aster oblongifolius</i>	Aromatic aster	Asteraceae	summer/fall forb
<i>Aster sericeus</i>	Western silvery aster	Asteraceae	summer/fall forb
<i>Astragalus canadensis</i>	Canada milk-vetch	Fabaceae	legume
<i>Astragalus crassicaarpus</i>	Ground-plum, prairie plum milk-vetch	Fabaceae	legume
<i>Astragalus lotiflorus</i>	Lotus milk-vetch	Fabaceae	legume
<i>Baptisia australis</i>	Blue wild indigo	Fabaceae	legume
<i>Baptisia bracteata</i> var. <i>leucophaea</i>	Long bract wild indigo	Fabaceae	legume
<i>Bouteloua curtipendula</i>	Side-oats grama-grass	Poaceae	warmgrass
<i>Bouteloua gracilis</i>	Blue grama	Poaceae	warmgrass
<i>Bouteloua hirsuta</i>	Hairy grama-grass	Poaceae	warmgrass
<i>Brickellia eupatorioides</i>	False boneset	Asteraceae	summer/fall forb
<i>Buchloe dactyloides</i>	Buffalograss	Poaceae	coolgrass
<i>Cacalia plantaginea</i>	Groovestem Indian plantain	Asteraceae	summer/fall forb
<i>Callirhoe alcaeoides</i>	Light poppy-mallow	Malvaceae	ephemeral
<i>Calylophus serrulatus</i>	Yellow sundrops	Onagraceae	spring forb
<i>Capsella bursa-pastoris</i>	Shepherd's purse	Brassicaceae	annual-biennial
<i>Carex amphibola</i>	Eastern narrowleaf sedge	Cyperaceae	grass-like

Scientific name	Common Name	Family	Guild
<i>Carex blanda</i>	Eastern woodland sedge	Cyperaceae	grass-like
<i>Carex brevior</i>	Shortbeak sedge	Cyperaceae	grass-like
<i>Carex meadii</i>	Mead's sedge	Cyperaceae	grass-like
<i>Ceanothus americanus</i>	New Jersey tea, redroot	Rhamnaceae	woody
<i>Ceanothus herbaceus</i>	Jersey tea	Rhamnaceae	woody
<i>Cerastium brachypodium</i>	Short-stalk chickweed	Caryophyllaceae	Perennial
<i>Chaerophyllum procumbens</i>	Spreading chervil	Apiaceae	annual-biennial
<i>Chamaesyce prostrata</i>	Prostrate sandmat	Euphorbiaceae	annual-biennial
<i>Chenopodium album</i>	Lamb's quarters, pigweed	Chenopodiaceae	annual-biennial
<i>Chenopodium berlandieri</i>	Pitseed goosefoot	Chenopodiaceae	annual-biennial
<i>Chloris verticillata</i>	Tumble windmill grass	Poaceae	coolgrass
<i>Cirsium altissimum</i>	Tall thistle	Asteraceae	annual-biennial
<i>Cirsium undulatum</i>	Wavy-leaved thistle	Asteraceae	summer/fall forb
<i>Clematis terniflora</i>	Sweet autumn virgin's bower	Ranunculaceae	woody
<i>Comandra umbellata</i>	Bastard toad-flax	Santalaceae	spring forb
<i>Convolvulus arvensis</i>	Field-bindweed	Convolvulaceae	summer/fall forb
<i>Conyza canadensis</i>	Canadian horseweed	Asteraceae	annual-biennial
<i>Cornus drummondii</i>	Rough-leaved dogwood	Cornaceae	woody
<i>Corydalis micrantha</i>	Small flower fumewort	Fumariaceae	annual-biennial
<i>Croton capitatus</i>	Hogwort	Euphorbiaceae	annual-biennial
<i>Croton monanthogynus</i>	Prairie-tea	Euphorbiaceae	annual-biennial
<i>Cynanchum laeve</i>	Honey vine	Asclepiadaceae	summer/fall forb
<i>Cyperus esculentus</i>	Chufa flatsedge	Cyperaceae	grass-like
<i>Dalea aurea</i>	Golden prairie clover	Fabaceae	legume
<i>Dalea candida</i>	White prairie clover	Fabaceae	legume
<i>Dalea multiflora</i>	Roundhead prairie clover	Fabaceae	legume
<i>Dalea purpurea</i>	Violet prairie clover	Fabaceae	legume
<i>Delphinium carolinianum</i>	Carolina larkspur	Ranunculaceae	spring forb
<i>Delphinium carolinianum</i> ssp. <i>Virescens</i>	Carolina larkspur	Ranunculaceae	spring forb
<i>Descurainia pinnata</i>	Western tansy-mustard	Brassicaceae	annual-biennial

Scientific name	Common Name	Family	Guild
Desmanthus illinoensis	Prairie bundleflower	Fabaceae	legume
Desmodium cuspidatum	Large bract tick-trefoil	Fabaceae	legume
Desmodium illinoense	Illinois tick-trefoil	Fabaceae	legume
Dichanthelium oligosanthes	Heller's rosettegrass	Poaceae	coolgrass
Digitaria cognata	Carolina crab grass	Poaceae	coolgrass
Draba brachycarpa	Shortpod draba	Brassicaceae	annual-biennial
Draba cuneifolia	Wedgeleaf draba	Brassicaceae	annual-biennial
Draba reptans	Carolina draba	Brassicaceae	annual-biennial
Echinacea angustifolia	Blacksamson coneflower	Asteraceae	summer/fall forb
Eleocharis compressa	Flat-stem spike-rush	Cyperaceae	grass-like
Ellisia nyctelea	Aunt Lucy	Hydrophyllaceae	annual-biennial
Elymus canadensis	Canada wild rye	Poaceae	coolgrass
Eragrostis spectabilis	Purple lovegrass	Poaceae	warmgrass
Erigeron philadelphicus	Philadelphia fleabane	Asteraceae	ephemeral
Erigeron strigosus	Prairie fleabane	Asteraceae	annual-biennial
Erythronium mesochoreum	Midland fawnlily	Liliaceae	ephemeral
Escobaria missouriensis var. Missouriensis	Missouri foxtail cactus	Cactaceae	succulent
Eupatorium altissimum	Tall thoroughwort	Asteraceae	summer/fall forb
Euphorbia corollata	Flowering spurge	Euphorbiaceae	summer/fall forb
Euphorbia dentata	Toothed spurge	Euphorbiaceae	annual-biennial
Euphorbia marginata	Snow-on-the-mountain	Euphorbiaceae	annual-biennial
Euphorbia spathulata	Warty spurge	Euphorbiaceae	annual-biennial
Euthamia gymnospermoides	Texas goldenrod	Asteraceae	summer/fall forb
Evolvulus nuttallianus	Shaggy dwarf morning-glory	Convolvulaceae	spring forb
Festuca subverticillata	Nodding fescue	Poaceae	coolgrass
Galium aparine	Stickywilly	Rubiaceae	annual-biennial
Galium circaezans	Licorice bedstraw	Rubiaceae	spring forb
Geranium carolinianum	Bricknell's crane's-bill	Geraniaceae	annual-biennial
Geum canadense	White avens	Rosaceae	spring forb
Grindelia squarrosa	Curly-top gum-weed	Asteraceae	annual-biennial

Scientific name	Common Name	Family	Guild
Hedeoma hispida	Rough false pennyroyal	Lamiaceae	annual-biennial
Hedyotis nigricans var. Nigricans	Diamondflowers	Rubiaceae	spring forb
Helianthus maximiliani	Maximilian sunflower	Asteraceae	summer/fall forb
Hieracium longipilum	Hairy hawkweed	Asteraceae	summer/fall forb
Hordeum pusillum	Little barley	Poaceae	coolgrass
Hybanthus verticillatus	Baby slippers	Violaceae	ephemeral
Hymenopappus scabiosaeus	Carolina woollywhite	Asteraceae	spring forb
Juncus interior	Inland rush	Juncaceae	grass-like
Kochia scoparia	Mexican fireweed	Chenopodiaceae	annual-biennial
Koeleria macrantha	Junegrass	Poaceae	coolgrass
Krigia cespitosa	Weedy dwarfdandelion	Asteraceae	annual-biennial
Kummerowia stipulacea	Korean clover	Fabaceae	legume
Lactuca serriola	Prickly lettuce	Asteraceae	annual-biennial
Lamium amplexicaule	Henbit dead nettle	Lamiaceae	annual-biennial
Laportea canadensis	Canadian woodnettle	Urticaceae	summer/fall forb
Leersia oryzoides	Rice cut-grass	Poaceae	warmgrass
Lepidium campestre	Field pepper weed	Brassicaceae	annual-biennial
Lepidium densiflorum	Common pepperweed	Brassicaceae	annual-biennial
Lespedeza capitata	Bush-clover	Fabaceae	legume
Lespedeza violacea	Violet lespedeza	Fabaceae	legume
Lespedeza virginica	Slender lespedeza	Fabaceae	legume
Liatris aspera	Tall blazing star	Asteraceae	summer/fall forb
Liatris punctata	Dotted blazing star, gay feather	Asteraceae	summer/fall forb
Linum sulcatum	Grooved flax	Linaceae	annual-biennial
Lithospermum incisum	Narrow-leaved stoneseed	Boraginaceae	spring forb
Lobelia cardinalis	Cardinal-flower	Campanulaceae	summer/fall forb
Lomatium foeniculaceum	Desert biscuitroot	Apiaceae	ephemeral
Malvastrum hispidum	Hispid false-mallow	Malvaceae	annual-biennial
Melilotus officinalis	Yellow sweet clover	Fabaceae	legume
Menispermum canadense	Common moonseed	Menispermaceae	woody

Scientific name	Common Name	Family	Guild
Mirabilis nyctaginea	Heart-leaf four o'clock	Nyctaginaceae	spring forb
Monarda fistulosa	Wild bergamot	Lamiaceae	summer/fall forb
Muhlenbergia cuspidata	Plains muhly	Poaceae	coolgrass
Muhlenbergia frondosa	Wirestem muhly	Poaceae	warmgrass
Myosotis verna	Spring forget-me-not	Boraginaceae	annual-biennial
Nothoscordum bivalve	Crowpoison	Liliaceae	ephemeral
Oenothera biennis	Common evening-primrose	Onagraceae	summer/fall forb
Oenothera macrocarpa	Big-fruit evening-primrose	Onagraceae	spring forb
Oenothera speciosa	Pink ladies	Onagraceae	spring forb
Onosmodium molle	Soft hair marbleseed	Boraginaceae	spring forb
Opuntia macrorhiza	Twistspine prickly pear	Cactaceae	succulent
Oxalis dillenii	Tufted yellow wood-sorrel	Oxalidaceae	spring forb
Oxalis violacea	Violet wood-sorrel	Oxalidaceae	spring forb
Panicum capillare	Witch-grass	Poaceae	warmgrass
Panicum virgatum	Switchgrass	Poaceae	warmgrass
Parthenocissus quinquefolia	Virginia-creeper, woodbine	Vitaceae	woody
Pascopyrum smithii	Western wheatgrass	Poaceae	coolgrass
Paspalum laeve	Field paspalum	Poaceae	warmgrass
Penstemon cobaea	Cobaea beardtongue	Scrophulariaceae	ephemeral
Penstemon tubiflorus	White-wand beard-tongue	Scrophulariaceae	spring forb
Phlox divaricata	Wild blue phlox	Polemoniaceae	spring forb
Physalis heterophylla	Clammy ground cherry	Solanaceae	spring forb
Physalis longifolia	Longleaf ground cherry	Solanaceae	spring forb
Physalis pumila	Dwarf ground cherry	Solanaceae	spring forb
Physalis virginiana	Virginia ground cherry	Solanaceae	spring forb
Phytolacca americana	American pokeweed, pokeberry	Phytolaccaceae	summer/fall forb
Plantago patagonica	Wooly plantain	Plantaginaceae	annual-biennial
Plantago pusilla	Dwarf plantain	Plantaginaceae	spring forb
Plantago rhodosperma	Redseed plantain	Plantaginaceae	annual-biennial
Plantago rugelii	Blackseed plantain	Plantaginaceae	spring forb

Scientific name	Common Name	Family	Guild
<i>Poa arida</i>	Plains bluegrass	Poaceae	coolgrass
<i>Poa pratensis</i>	Kentucky bluegrass	Poaceae	coolgrass
<i>Polygala verticillata</i>	Whorled milkwort	Polygalaceae	annual-biennial
<i>Polygonum virginianum</i>	Jumpseed	Polygonaceae	summer/fall forb
<i>Psoralea argophylla</i>	Silverleaf Indian breadroot	Fabaceae	legume
<i>Psoralea esculenta</i>	Large Indian breadroot	Fabaceae	legume
<i>Psoralea tenuiflorum</i>	Slim-flower scurf-pea	Fabaceae	legume
<i>Ratibida columnifera</i>	Upright coneflower	Asteraceae	summer/fall forb
<i>Rhus glabra</i>	Smooth sumac	Anacardiaceae	woody
<i>Ribes missouriense</i>	Missouri gooseberry	Grossulariaceae	woody
<i>Rosa arkansana</i>	Prairie rose	Rosaceae	woody
<i>Ruellia humilis</i>	Fringeleaf wild petunia	Acanthaceae	summer/fall forb
<i>Ruellia strepens</i>	Limestone wild petunia	Acanthaceae	summer/fall forb
<i>Rumex crispus</i>	Curly dock	Polygonaceae	spring forb
<i>Salvia azurea</i>	Azure blue sage	Lamiaceae	summer/fall forb
<i>Sambucus canadensis</i>	Common elderberry	Caprifoliaceae	woody
<i>Schizachyrium scoparium</i>	Little bluestem	Poaceae	warmgrass
<i>Schrankia nuttallii</i>	Nuttallii sensitive brier	Fabaceae	legume
<i>Scutellaria parvula</i>	Small skullcap	Lamiaceae	spring forb
<i>Senecio plattensis</i>	Platte groundsel	Asteraceae	summer/fall forb
<i>Setaria viridis</i>	Green bristlegrass	Poaceae	warmgrass
<i>Sida spinosa</i>	Prickly fanpetals	Malvaceae	annual-biennial
<i>Silene antirrhina</i>	Sleepy silene	Caryophyllaceae	annual-biennial
<i>Silphium laciniatum</i>	Compass-plant	Asteraceae	summer/fall forb
<i>Sisyrinchium campestre</i>	Prairie blue-eyed grass	Iridaceae	ephemeral
<i>Smilax tamnoides</i>	Bristly greenbrier	Smilacaceae	woody
<i>Solanum carolinense</i>	Carolina horse-nettle	Solanaceae	spring forb
<i>Solanum rostratum</i>	Buffalo-bur night-shade	Solanaceae	annual-biennial
<i>Solidago canadensis</i>	Canada goldenrod	Asteraceae	summer/fall forb
<i>Solidago canadensis</i> var. <i>Gilvocanescens</i>	Shorthair goldenrod	Asteraceae	summer/fall forb
<i>Solidago missouriensis</i>	Missouri goldenrod	Asteraceae	summer/fall forb

Scientific name	Common Name	Family	Guild
<i>Solidago rigida</i>	Stiff goldenrod	Asteraceae	summer/fall forb
<i>Sorghastrum nutans</i>	Indian grass	Poaceae	warmgrass
<i>Spermolepis inermis</i>	Red river scaleseed	Apiaceae	annual-biennial
<i>Spiranthes cernua</i>	Nodding ladies' tresses	Orchidaceae	summer/fall forb
<i>Sporobolus asper</i>	Rough dropseed	Poaceae	warmgrass
<i>Sporobolus neglectus</i>	Puffsheath dropseed	Poaceae	warmgrass
<i>Stellaria media</i>	Common chickweed	Caryophyllaceae	annual-biennial
<i>Strophostyles leiosperma</i>	Silkseed fuzzy bean	Fabaceae	legume
<i>Symphoricarpos orbiculatus</i>	Coralberry	Caprifoliaceae	woody
<i>Taraxacum officinale</i>	Common dandelion	Asteraceae	spring forb
<i>Teucrium canadense</i>	Canada germander	Lamiaceae	summer/fall forb
<i>Thlaspi arvense</i>	Field penny-cress	Brassicaceae	annual-biennial
<i>Toxicodendron radicans</i>	Eastern poison-ivy	Anacardiaceae	woody
<i>Tradescantia bracteata</i>	Longbract spiderwort	Commelinaceae	spring forb
<i>Tradescantia ohimensis</i>	Bluejacket spiderwort	Commelinaceae	spring forb
<i>Trichostema brachiatum</i>	Fluxweed	Lamiaceae	annual-biennial
<i>Tridens flavus</i>	Purpletop tridens	Poaceae	warmgrass
<i>Triodanis leptocarpa</i>	Slimpod venus' looking glass	Campanulaceae	annual-biennial
<i>Triodanis perfoliata</i>	Clasping venus' looking glass	Campanulaceae	annual-biennial
<i>Urtica dioica</i> ssp. <i>Gracilis</i>	California nettle, stinging nettle	Urticaceae	summer/fall forb
<i>Verbena simplex</i>	Narrow-leaved vervain	Verbenaceae	spring forb
<i>Verbena stricta</i>	Hoary vervain	Verbenaceae	spring forb
<i>Verbesina alternifolia</i>	Wingstem	Asteraceae	summer/fall forb
<i>Vernonia baldwinii</i>	Baldwin's ironweed	Asteraceae	summer/fall forb
<i>Veronica arvensis</i>	Corn speedwell	Scrophulariaceae	annual-biennial
<i>Veronica peregrina</i>	Neckweed	Scrophulariaceae	annual-biennial
<i>Viola bicolor</i>	Field pansy	Violaceae	annual-biennial
<i>Viola pedatifida</i>	Prairie violet	Violaceae	spring forb

Scientific name	Common Name	Family	Guild
<i>Viola pratincola</i>	Northern bog violet	Violaceae	ephemeral
<i>Viola sororia</i>	Common blue violet	Violaceae	spring forb
<i>Vitis riparia</i>	Riverbank grape	Vitaceae	woody
<i>Vulpia octoflora</i>	Six-weeks fescue	Poaceae	coolgrass
<i>Xanthium strumarium</i>	Rough cocklebur	Asteraceae	annual-biennial
<i>Zanthoxylum americanum</i>	Common prickly ash	Rutaceae	woody
<i>Zigadenus elegans</i>	Mountain death camas	Liliaceae	summer/fall forb
<i>Zigadenus nuttallii</i>	Nuttall's deathcamas	Liliaceae	spring forb
<i>Zizia aurea</i>	Golden zizia	Apiaceae	spring forb

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U.S. Department of the Interior



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